UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

An Investigation into the Best Structural Material for the New SUB

Sheldon Sequeira

Jérôme Pomerleau

William Wei Xing

University of British Columbia

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Presented to: Dr. Patricia Dawn Mills

Submitted by:

Sheldon Sequeira

Jérôme Pomerleau

William Wei Xing

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ABSTRACT

The University of British Columbia is a leader in terms of sustainability in North America. The Centre for Interactive Research on Sustainability at UBC showcases this leadership. The development plans for a new Student Union Building are to be completed by 2014. The new SUB will provide improved services to the student community. As heard in the conference given by Mr. Robinson from the CIRS, every new building on campus has to be more sustainable than the previous built. Many new technologies are available to make this building as sustainable as possible. The building structure is an important part of the project.

A laminated wood structure has been proven in the past to present the best solution for this application. Some limitations like height and the load of the structure can stop the possibility of using wood, but in this case, everything seems to be acceptable for a laminated wood structure. Many factors have proven that wood is by far the most sustainable building material. Energy consumption is lower when you produce woods beam than steel or concrete and also act as insulation for the building which contributes in reducing heating and cooling cost. The waste generated by manufacturing steel or concrete is a lot higher than manufacturing wood. The time for mounting the structure is also a big economic factor when you use wood, i.e. wood beams are like a puzzle to mount and once it is mounted it is easier to fix electrical components and others with less energy than other structures type. The fact that the structure can be made of local products is also a big incentive. Wood from British Columbia and manufactured in the province is to be considered. It reduces transportation cost and pollution, as well as it will reduce the carbon dioxide produces from the trees being killed by a beetle invasion. In fact, these trees have to be used for different types of application because without being used, it will generate a huge waste of wood generating carbon dioxide. Earthquake safety is also an issue for tall buildings. The wood acts more like an absorber than a transmitter during the earthquake compared to steel and concrete which require structural shock absorbers. The social aspect is that it will help people feeling a natural environment and create jobs for people from British Columbia. Every environmental aspect also contributes to help our society having a better social side of their lives. There is no doubt that the wood will be the best choice to fill every requirement from UBC and the sustainable program.

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GLOSSARY

Global Warming Potential	a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming
Glulam	Structural timber product manufactured by gluing together individual pieces of dimension lumber under controlled conditions.
Laminated Veneer Lumber	a product that uses multiple layers of thinly cut lumber bonded together with adhesives
Rotary Lathe	a mechanical tool which rotates a block of material about an axis allowing an object to be cut from the block with symmetry about an axis

1.0 INTRODUCTION

In the design of buildings, we are usually given a choice three materials, namely concrete, steel, and wood. Nowadays, wood is becoming increasingly popular among architects due to its lightweight, high density, low costs, ease of construction, availability, durability, positive impacts on the environment, and it cause less casualties in the event of earthquakes. Many schools, hospitals, factories, corporate offices residential houses and governmental buildings are increasingly choosing wood as the material of construction.

Wood is a high performance material, it is relatively inexpensive, 100% renewable, and most wooden houses last in the range of 80 to 100 years. Wood due to its thermal properties, are much better insulators than its alternatives. A wall built with half the thickness using wood compared to concrete provide double the amount of thermal insulation value, this feature saves energy consumption, and also free up more space inside the buildings. Wood is environmental friendly, they help to reduce the amount of carbon dioxide in the atmosphere during the process of reforestation and generates less greenhouse gas. In the event of fire, wood behaves much more predictable than steel, thus making fire rescue efforts easier and safer.

In this report, a triple bottom line assessment is conducted on the use of wood in building construction, by considering its economical, environmental and social impacts. We shall discuss in detail the advantages and disadvantages of using wood and compare it to concrete and steel. In the end, based on our findings a recommendation will be provided regarding what material the new student union building should use in construction.

2.0 ENVIRONMENTAL ASSESSMENT

In modern building design, we are usually given a choice of three materials, wood, steel and concrete. Human activities affect the environment, and thus it necessary to consider the environmental effects in the design of buildings. The use of wood over concrete and steel brings many important environmental benefits including low energy usage, low greenhouse gas emissions, less air and water pollution, act as better insulators, produce less solid waste, and etc. Thus, wood is increasingly becoming the material of choice in the construction of many residual houses, schools, hospitals, corporate buildings, and governmental offices.

Of the three mentioned materials, wood is biodegradable and is the only material that is 100% renewable. It can be recycled and reused with very little additional energy as it makes use of solar energy to renew itself in a sustainable cycle. Concrete, however cannot be reused in the same form but can be downgraded to aggregate with a lot additional energy. The use of wood has the lowest Ecological Resource Use index value because as wood is harvested, reforestation follows and thus it has a relatively short term effect on the environment. In addition, the process of growing trees absorbs carbon dioxide from the atmosphere, and thus helps to tackle global warming.

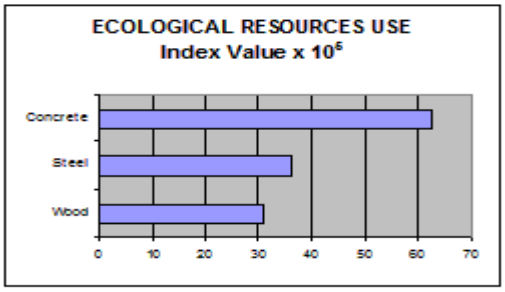

Figure 1: Comparison of Ecological Resource Use for three materials

<http://www.tealjones.com/BenefitsOfWood.htm>

The use of wood in the construction of homes reduces the amount of air pollution emissions (i.e. sulphur dioxide, nitrous dioxide, methane, and particulate) and water pollution released into the environment as shown in the charts below. Wood products are also known to

produce less solid compared to the use of steel and concrete, both in manufacturing of the products and at the construction sites.

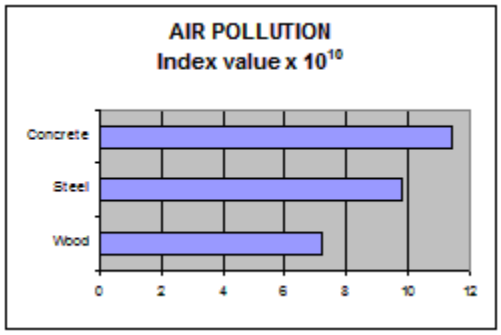

Figure 2: Comparison of Air Pollution for three materials

< http://www.tealjones.com/BenefitsOfWood.htm>

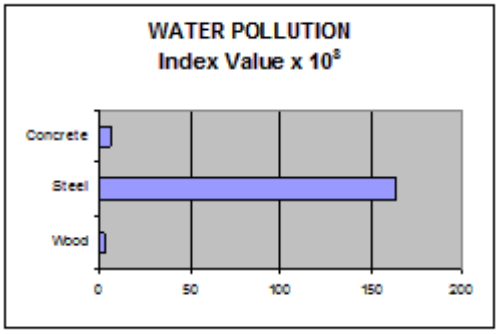

Figure 3: Comparison of Water Pollution for three materials

<http://www.tealjones.com/BenefitsOfWood.htm>

The use of wood over concrete and steel saves energy for the environment; it requires hardly any fossil fuels to produce, generates less greenhouse gasses and reduces the amount of carbon dioxide emissions to the environment. In a study conducted by the Consortium for Research on Renewable Industrial Materials, a non-profit organization formed to research on the use of wood in construction, it was discovered that the use of steel and concrete in building homes consumed 17% and 16% more energy than wood, respectively. The energy consumed includes not only electricity, but also diesel and fuel to extract and haul materials. In addition it was concluded that the global warming potential of concrete -frame homes and steel-frame homes are 31% and 26% higher than wood frame homes, respectively.

MINNEAPOLIS DESIGN	Wood	Steel	Difference	Other design vs. wood (% change)
Embodied Energy (GJ)	651	764	113	17%
Global Warming Potential (CO_2 kg)	37,047	46,826	9,779	26%
Air Emission Index (index scale)	8,566	9,729	1,163	14%
Water Emission Index (index scale)	17	70	53	312%
Solid Waste (total kg)	13,766	13,641	-125	-0.9%

ATLANTA DESIGN	Wood	Concrete	Difference	Other design vs. wood (% change)
Embodied Energy (GJ)	398	461	63	16%
Global Warming Potential (CO_2 kg)	21,367	28,004	6,637	31%
Air Emission Index (index scale)	4,893	6,006	1,114	23%
Water Emission Index (index scale)	7	7	0	0%
Solid Waste (total kg)	7,442	11,269	3,827	51%

Figure 4: Comparison of different environment values for three materials

Another important benefit of wood is that it is resistance to some of the corrosive chemicals that is harmful to steel and concrete. For example, wood is much more suited in building construction when they are exposed to the following: organic compounds, hot or cold solutions of acids or neutral salts, dilute acids, and high relative humidity.

Wood products are much more efficient insulators than concrete or steel. This is because the cellular structure of wood contains air pockets that limit its ability to conduct heat whereas steel and concrete create thermal bridges that permit heat transfer. Studies have shown that external Walls built using wood with half the thickness of a concrete wall were discovered to provide twice the thermal insulation value. This feature of wood further saves energy consumption in both heating and cooling.

3.0 ECONOMIC ASSESSMENT

The new SUB requires a structure that can support 5 floors. The required quantity of glulam beams is not exactly known because it has yet to be evaluated by architects and civil engineers, so a general economic impact study is made to present the advantages of using wood instead of concrete and steel. Currently, British Columbia is facing a major problem in its pine forest. In fact, it is the worst mountain pine beetle infestation in the history (BC Stats 2009). This tiny insect is taking advantage of the climate change. Warm and dry summers coupled with mild winters are the main factors why the beetle's population is so high. In some regions of BC, two-third of the pine trees were infested in 2008 and it has not improved from this time (BC Stats 2009). If this wood is not used, it will hurt small cities and the wood industry in some part of BC. It has to be considered as a major economic impact. The environmental side of this disaster is that by being eaten by the beetles, pine is releasing carbon dioxide in the atmosphere instead of absorbing it. This natural destruction represents three quarters of all the emissions generated by annual forest fire (BC Stats 2009). As one of the largest universities in Canada, UBC is in a good position to look forward with a beetle wood structure with this project. The construction of the new SUB can showcase the many applications of wood. The government of British Columbia is currently investigating solutions to make the best possible use of this wood. UBC can help BC by using wood as a structural material.

Glulam is also improving the time factor. Indeed, every beam is manufactured and shipped to the construction site where the 'puzzle' can be mounted. It saves time and money. In addition to the pre-manufactured structure, this type of structure doesn't need perfect weather conditions like concrete to take place. Building the new SUB will require many tools and machines, but with laminated wood a smaller crane can be used due to the low density of its structure. Once the structure is mounted, it is easier to fix the electrical component through wood than steel or concrete: 'Our electrical fix was supposed to take eight weeks, it took three.' (AM, 2009). This type of structure is also the easiest to modify, if the SUB needs different configuration in the future, the wood structure can take different setup. This material is also well known for having no restriction in matching other materials, so many combinations can be made to reach the most efficient and sustainable building as possible. Therefore, engineers are required for every major modification to the structure because drilling holes or adding weight

can result in failure of the structure. All these facts help in reducing the cost of a five-floor building.

As evaluated in the environmental impact section, the laminated wood requires much less energy to manufacture than steel or moulding concrete on site. Energy is not free and the more it is required, the more expensive it will be to build the structure. Trees only use energy from the sun and water, nutrients from the soil, and carbon dioxide from the atmosphere to manufacture wood.

Wood is the only major building material that is renewable, compared to steel and concrete. Solid waste created by wood structure can be recycled for many applications like medium density fiberboard (MDF), finger joint lumber and composite lumber. Steel is the only other material that offers recyclable possibilities because concrete is moulded with specifications that cannot really apply to another product. After the building's lifetime, wood can be reused on campus or sold to different organizations; in both cases it generates money for the university.

Insulation is another part where the wood is doing very good. It has thermal insulation qualities superior to any other building materials; it keeps the cold outside in winter and the heat inside during summer. Temperature control is very important in a crowded building such as the SUB; it is why a good insulation will reduce cost in heating and cooling. The figures below represent the wood performance in thermal resistance compare to steel and concrete.

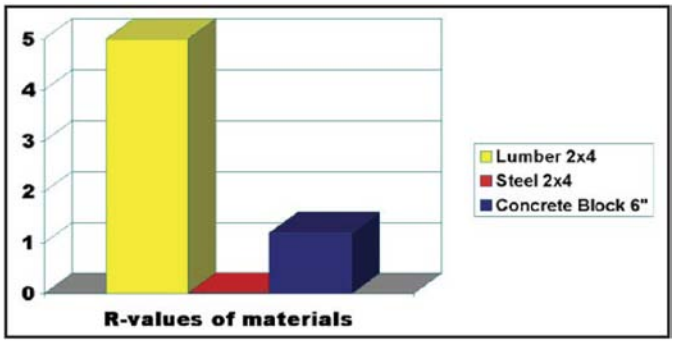

Figure 5: The 'R' value representing insulation effectiveness

< http://www.cwc.ca>

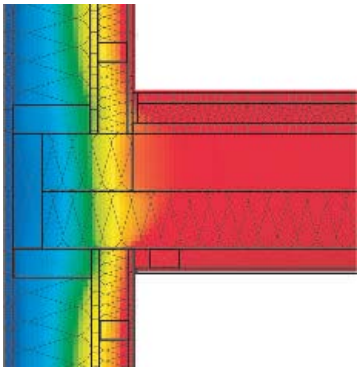

Figure 6: Heat transfer through wood wall

<http://www.roadmap2010.eu>

British Columbia, being a world leader in wood manufacturing offers a local product. Using BC woods eliminate extra cost for shipping steel from overseas and big ready-mix truck to carry concrete from the plant to the construction site. Wood is also lighter than steel and more beams can be shipped on the same truck using less fuel. Saving on shipping decreases total cost for the whole project.

The University of British Columbia is situated on the most earthquake-prone region of Canada and the BC building code requires good structures to resist to these natural disasters (Seismic Waves,2009) Steel's stiffness is transmitting every type of vibration through the building which is not ideal when there is an earthquake. Steel and concrete structures require absorber to survive earthquakes, but wood does not require such as absorber. At the present time, the building code allows wood structure for five stories maximum. Particularly, the wood absorbs vibrations instead of transmitting. Therefore, absorbers are not added as extra cost for this type of structure. It is another reason why it cost less to construct with wood than steel and concrete.

4.0 SOCIAL ASSESSMENT

One of the oldest and most popular construction materials is wood. Unlike both steel and concrete, wood is a naturally renewable building material. Advances in structural laminated wood allow for wood structures to reach heights never possible before. The use of wood instead of conventional reinforced concrete would definitely result in different social implications. Both those involved in the construction of the new Student Union Building and those utilizing the new building after construction would be affected by the use of laminated veneer lumber (LVL). However, the use of wood as a primary building material is somewhat limited due to building codes.

Firstly, the use of laminated wood as the building material for the new Student Union Building would shorten on-site construction time. Laminated veneer lumber is formed by first thinly slicing a log using a rotary lathe. Then, the thin sheets of wood are dried and bonded together using an adhesive (Kimura, 2000). On-site installation of steel beams would require bolting and welding. On the other hand, laminated wood does not need to be joined by these conventional means. It is not necessary to join laminated wood beams because portions of the structure can be formed by a single piece of laminated wood (Kimura, 2000). This property of LVL greatly improves the workability of the material on-site and allows for a relatively quick installation. Recently in the London borough of Hackney, a nine-story multifamily building was constructed entirely in timber (See Figure 7 below). The use of wood "allowing the entire structural frame to be completed by four people in 27 days, using little more than a portable crane and handheld electric screwdrivers" (AM, 2009). As mentioned earlier, wood beams are also lighter than conventional steel beams. In additional to requiring less fuel for transport, this property of wood also allows for easier handling by workers on-site.

As the primary users of the new Student Union Building, students of UBC will be affected by the choice of building material. As a highly effective insulator, wood is able minimize heat transfer and heat loss. Additionally, wood is a poor conductor compared to steel (Kurt, Ozcan, & Uysal, 2009). Therefore, outdoor temperature variations are not passed on by a laminated wood frame. These properties of wood contribute to excellent living conditions during both summer and winter.

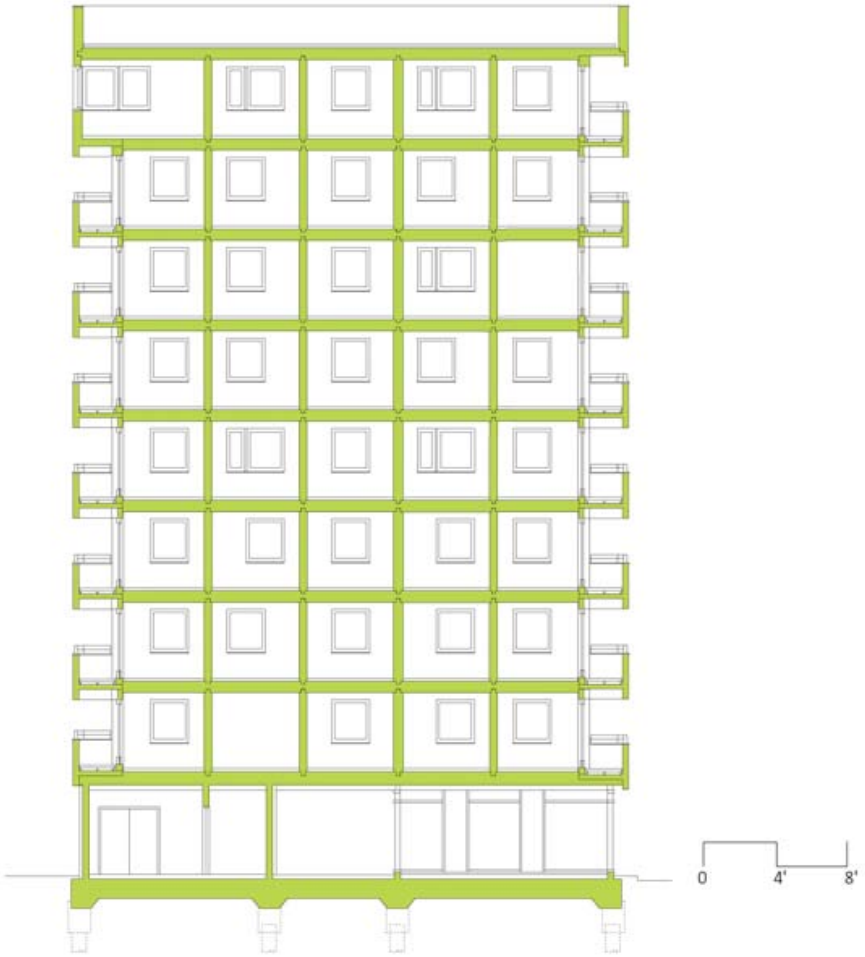

Figure 7: Building Section of the Murray Grove in Hackney

<http://www.architectmagazine.com/detail/murray-grove.aspx>

Unfortunately due to limitations from the Building and Fire Code, buildings cannot be made completely out of wood. Dr. Frank Lam, Professor for the University of British Columbia's Wood Science Department, believes further investigation into wood structures will proves this technology is not as hazardous as many believe. Dr. Lam states that a wood structure should not be the biggest concern in case of a building fire. Fumes from burning furniture are more toxic than the fumes from burring timber. While a wood structure may burn in the event of a fire, it should be acknowledged that steel beams may melt during a fire.

Using laminated wood as the structural material for the new Student Union Building would benefit both the workers involved in the construction of the building, and those using the

building after completion of construction. The prefabrication process of laminated veneer lumber allows for shortened on-site installation and results in fewer disturbances to regular campus activities. Due to its properties as an excellent insulator and poor conductor, wood would allow for the most ideal living conditions after construction. According to Dr. Lam, wood structures are very versatile and are able to join with almost every other structure type. This makes wood the ideal candidate for a hybrid construction and allows for easy renovations and modifications after initial construction.

5.0 CONCLUSION

In conclusion, after evaluating laminate wood construction against conventional reinforced concrete construction using a triple-bottom line assessment, it is clear that wood is the more sustainable option. Not only does the fabrication of laminate wood consume less energy, but the construction of a laminate wood structure on-site requires less energy than a concrete and steel structure. Moreover, a laminate wood structure would also cost less financially. Lastly, a social assessment of wood as a building material showed it benefitted both those involved in the construction of the new SUB, and the future occupants of the new building.

The environmental portion of our assessment states that a wood structure would result in fewer greenhouse gas emissions than a traditional concrete and steel structure. Also, the fabrication and use of laminate wood produces less air and water pollution than the competitor. Wood is an excellent insulator and thus the heating cost for a wooden structure is lower than that of a concrete and steel structure. Once the new SUB has reached the end of its lifecycle, the wood structure can be recycled reducing waste.

From a financial standpoint, using local wood from British Columbia would minimize transportation costs. On-site construction is also simplified when using laminate wood and thus the cost of construction and installation will be reduced. Using a wood structure would also eliminate the need for absorbers. On the other hand, using a concrete and steel structure would require these absorbers as a safety precaution in case of an earthquake. Heating costs would be lowered if wood was chosen as the structural material of the new SUB.

Finally, using laminated veneer lumber would shorten on-site construction time due to preparations done during the prefabrication process. This shorted construction time would minimize disturbances on-campus. Handling wooden beams is also more manageable for workers since wood is lighter than steel or concrete. Being a good insulator and poor conductor of heat makes wood the ideal choice for improved living conditions in the new SUB.

By using the resources available at the UBC library, researching articles online, and interviewing an expert in the field of wood structures, a triple-bottom line assessment of laminate wood was conducted. The investigation has shown that wood is more sustainable in all three areas of the triple-bottom line assessment.

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